INSECT RESISTANCE OF THE TOMATO, *Lycopersicon esculentum* (Mill.)

by

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INTRODUCTION

Insect Pests of Tomatoes

A large number of insects are known to attack tomatoes, many of which are common in Kansas. Chemical control measures frequently cannot be used because they attack fruits near harvest and chemical residues result from spraying. The most important insect pests of tomatoes in Kansas are:

The potato aphid, *Macrosiphum solanifolii* (Ash) and the green peach aphid, *Myzus persicae* (Sulz.) both occur on tomatoes. They are sucking insects and may injure plants by sucking juice from their leaves and killing tissue or by spreading virus diseases. Aphids feed on the lower surface of the leaves and are more commonly a problem in cool weather. Their feeding causes stunting of the growing tips. Injury to the stems of the blossom cluster results in poor fruit set (26).

Several species of blister beetles attack tomatoes in Kansas, of which the most common ones are: *Epicauta lemniscata* (Fab.) (striped blister beetle), *Epicauta cinera* (Forst) (gray blister beetle) and *Macrobasis immaculata* (Say) (8). All species have similar feeding habits and can seriously defoliate the plants and destroy fruits as well.

There are several species of cutworms such as the variegated cutworm, *Peridroma margaritosa* (Haw.) which injure tomatoes in Kansas. The cutworms do their injury at night or on dark cloudy days. They cut off stems, above or below the ground, feed on roots, or climb up and feed on foliage.

The tomato fruitworm, *Heliothis armigera* (Hbn), Family Noctuidae, also known as the corn earworm and cotton bollworm, is a serious pest of tomatoes in Kansas. The infestation of this insect becomes more severe after nearby

EXPLANATION OF PLATE I

Field plot showing all four replicates of the 25 varieties. Late August 1963

PLATE I

corn has been harvested or reaches maturity. In Kansas there are usually three generations per year (8).

The tomato hornworm, Protoparce quinquemaculata (Haw.), Family Sphingidae, and the tobacco hornworm, P. sexta larvae frequently feed on tomatoes. Most of their damage consists of defoliating the plants, but they may also attack the immature fruits.

Grasshoppers frequently cause serious damage to tomatoes in Kansas (8). Although a large number of species occur, the two most harmful species to several crops in Kansas are Melanoplus bivittatus (Say) and Melanoplus mexicanus mexicanus (Sauss).

The two spotted spider mite, Tetranychus telarius (L.) can and frequently does cause severe damage to tomatoes by sucking plant juices from the lower leaf surfaces. They are often a special problem for control and require a thorough spray schedule.

Insect Control by Host Plant Resistance

There are several cases where resistant varieties have become the major means of insect control. Outstanding examples of this are the control of the grape phylloxera, Phylloxera vitifoliae (Fitch) by growing resistant grape varieties, and the control of leafhoppers of the genus Empoasca in African cotton plantations by growing resistant cotton varieties (21).

However, it is as an aid to other control measures that insect resistance is most important and may be most commonly used (21). Painter (21) cited several cases which all strongly suggested that the combination of chemical control and resistant varieties may prove more effective when control cannot be obtained by either method alone. Such control may come about either through the independent, though cumulative, effect of the two methods or through some

effect of the resistant variety on the physiology of the insect, making it more easily killed by the insecticide.

Purpose of Study

The purpose of this study was to make a survey of possible sources of insect resistance among several commercial tomato varieties. The choice of a group of commercial varieties rather than a group of plant introductions was made because it was felt that if sources of insect resistance should exist among commercial varieties, these then probably could be incorporated faster in new varieties than if the desirable character should come from a foreign plant introduction. There are a number of insects for which host resistance would be very helpful to tomato growers. The advantages of growing varieties resistant to some of these pests would basically be twofold:

1. Cheaper control. The tomato grower would have a smaller outlay for insecticides and labor of applying them.
2. Several insects attack tomatoes near or during the harvest season. Chemicals often cannot be applied safely during this time because residues will remain on the fruits after spraying or dusting.

LITERATURE REVIEW

Insect Resistance in General

The concept of insect resistance is a relatively new one. One of the first reports was given by Lindley (17), who in 1831 noted that the apple variety Winter Majetin was resistant to the wooly apple aphid, _Eriosoma lanigerum_ (Hausm.). Early reports of wheat varieties resistant to the hessian fly _Phytophaga destructor_ (Say) were given in 1785.

A classical example of the application of insect resistance to economic usefulness is the case of phylloxera resistant grape vines. Painter (21) describes how in 1871 the shipping of American grape varieties to France which were resistant to the grape phylloxera, *Phylloxera vitifoliae* (Fitch) saved that country from an economical catastrophe.

Painter (21) classifies insect resistance as seen in the field into three basic mechanisms which are interrelated as shown in the following diagram:

PREFERENCE → ANTIBIOSIS

For oviposition, food or shelter

Adverse effect of plant on biology of insect

TOLERANCE

Repair, recovery or ability to withstand infection

Insect Resistance in Tomatoes

Colorado Potato Beetle, *Leptinotarsa decemlineata* (Say). European research workers have paid much attention to this insect. Tomatoes, a near relative to *Solanum tuberosum*, have long been known to have a high degree of resistance to the potato beetle. Kuhn *et al* (16) found that the alkaloid glycosides tomatin (an extract of tomatoes) and demissin (an extract from *Solanum demissum*) were very similar in their effect upon the larvae of the beetle when potato leaves were injected with them. The larvae feeding on these leaves died nearly as fast as did those which did not get anything to eat. Apparently these substances do not poison the larvae but act as repellents. Thus the larvae die from starvation. Schaper (24) found that tomato

plants were most susceptible in the younger stages of growth, but that they showed an increasing resistance as they reached maturity. Schreiber (25, 26) feels that resistance due to the above mentioned alkaloid glycosides can be traced to the steroid metabolism of the larvae. In Canada, Gibson et al (12) were unable to raise larvae of the potato beetle when given only leaves of tomato plants. Brues (6) in Massachusetts was unable to obtain a second generation of adults on a diet of only tomato leaves.

Distinct differences between tomato varieties in relation to larval development were noted by Boczkowska (3), Kozlovsky (15) and Alfaro (1). The latter found that in Spain the beetle could complete its life cycle on any of the 18 tomato varieties which he tested. He did however find a significant difference in survival of the larvae and reproduction rate when raised on the different varieties. The work by Chin (7) may explain some of the contradictory results of above mentioned workers. It was found that when the larvae have a choice, they eat a relatively larger quantity of less preferred food plants, including the tomato, when the temperature is above optimum for feeding (approx. 32 degrees C.). Jermy (13) believes that since nutrition has no effect on host selection of the adult that there is little probability for the appearance of a "tomato strain" of Leptinotarsa, even in countries where, owing to an intensive cultivation of this plant, there are many possibilities for conditioning influences.

Hornworms (Plate II). Yamamoto and Fraenkel (36) found that oviposition and feeding of the tobacco hornworm, Protoparce sexta, (Haw.) are almost entirely restricted to plants of the Solanaceae. Oviposition is initiated by olfactory stimuli widely distributed in this family. Both in the field and in the laboratory, the moths preferred tomato foliage over other solanaceous plants for oviposition. However, in tobacco growing areas, tobacco has been

EXPLANATION OF PLATE II

Nearly full grown larva of the tomato hornworm, *Protoparce quinquemaculata* (Haw.) on a defoliated plant. July 1963

PLATE II

reported as the preferred plant for _P. sexta_ (18). In another paper Yamamoto and Fraenkel (37) stated that the specificity of the moth of _P. sexta_ could be attributed to two specific chemical stimuli. The chemicals affording the stimulation necessary for oviposition apparently occur only in solanaceous plants and the response to these chemicals may be considered to be part of the genetic constitution of the moths. However, preferences for only a few individual plants within the family Solanaceae appear to be responses induced by habituation to other chemical factors present only in specific plants. The same workers (38) isolated a gustatory stimulant for the larvae of _P. sexta_ from tomato and related plants of the Solanaceae. Preliminary characterizations indicate the material to be a glycosidic substance. The same material is also active as a feeding stimulant for the Colorado potato beetle. Waldbauer and Fraenkel (32) found that amputation of the maxillae of _P. sexta_ led to continuous feeding on dandelion, _Taraxacum officinale_ (Weber), a normally rejected plant. After the larvae became adapted to dandelion, they usually chose it over tomato in preference tests. Waldbauer (31) found that growth and reproduction of maxillectomized larvae were normal on _Taraxacum officinale_, reasonably good on _Arctium minus_ but poor on _Verbascum thapus_ and _Catalpa speciosa_.

Aphids, _Macrosiphum solanifolii_ (Ash.) and _Myzus persicae_ (Sulz.). McKinney (19) reported that in Arizona, tomatoes became infested with the green peach aphid (M. persicae) during April and that the flower thrips, _Frankliniella tritici_, (Fitch) were also present in large numbers for a time, but early in May these insects had disappeared and the plants had suffered no apparent injury. He thought that these insects had disappeared because their feet became entangled in a gumlike secretion or exudate from the tomato foliage.

West (33) studied the effect of differences in nutrition of tomatoes on populations of M. solanifolii. An infestation of 40 or more aphids per gram of plant tissue constitute a heavy or critical infestation, that affects significantly the metabolism and growth of host plants, even when conditions for plant growth are optimum (34). A dense infestation of aphids tends to outrun the capacity of the host plant to produce food and then to reduce the rate of food production. The effects are much more sudden in their results in the case of the plants growing in solutions deficient in any one of the following nutrients: calcium, magnesium, potassium, phosphorus, and especially nitrogen. At very low levels of nitrogen in the nutrient solution, a large percentage of the first instar aphid nymphs failed to establish themselves upon the host plant and died from lack of nutrition or from desiccation. West (33) concluded that there is reason to believe that aphid population increases are closely related with the rate of some phase of protein synthesis in plant tissue.

A general hypothesis by Kennedy (14) may also have value in this case. He found that growing and senescing leaves of certain plants were more susceptible to Myzus persicae and Aphis fabae (Scop.) than mature green leaves of the same plants. He proposed that the aphids' food (phloem sieve-tube sap) would be especially rich in soluble organic nitrogen compounds of high nutritive value (amino acids and amides) at or near places where growth and hence protein synthesis was going on in the plant. There would also be many free amino acids and amides where senescence with protein breakdown was going on. The tissue would, however, be poor in these compounds where neither growth nor senescence was in progress, as in mature green leaves. It is also known that intermittent wilting favors aphids in some cases. According to Kennedy (14) this could be possible because intermittent wilting favors the

progressive type of senescence, which in turn causes an increase in translocatory amino-nitrogen (11).

Two Spotted Spider Mite, *Tetranychus telarius*, (L.). Rodriguez (23) found that when the concentration of all major elements in a nutrient solution of tomatoes was doubled, the mites feeding on these plants produced twice the number of progeny. Moutia (20) thought that one of the factors which contributed to the increase of populations of *Tetranychus* species on tomato in Mauritius might be the newly developed practice of applying nitrophosphate fertilizers to this crop.

From North Carolina (30) it was reported that the variety Campbell 135 was highly resistant to an infestation which damaged Homestead 24 severely. Campbell 146 was intermediate.

Tomato Fruitworm, *Heliothis armigera* (Hbn.). Essig and Michelbacher (9) stated that in California tomato varieties which produced the most abundant and conspicuous blossoms were consistently most heavily infested with the larvae of the fruitworm. They also mentioned that some farmers believed that the pear shaped tomatoes were less seriously injured than the standard varieties. Wilcox *et al* (35) found that the percentage of damage increased on the larger plants. Apparently the moths laid more eggs on large plants than on small plants.

MATERIALS AND METHODS

Cultivation

On March 19, 1963, seed of 25 commercial tomato varieties was sown in sterilized quartz sand in greenhouse flats. On April 2 the seedlings were

transplanted to peatmoss pots (2 1/2 x 2 1/2 inches) containing a sterilized soil mixture of 1 part sand, 2 parts loam and 1 part rotten manure.

These plants were kept in the greenhouse until April 24 when they were transferred to a hotbed.

On May 9, the plants were planted in the field at the Ashland Horticultural Experiment Farm near Manhattan. Planting distances were 5 ft. in the rows and 6 ft. between rows. Each row consisted of 4 plants. The experiment was replicated 4 times and the varieties were randomized within each replicate. Thus for each variety a total of 16 plants were under observation. A guard row was planted parallel and adjacent to the outer rows. At the time of planting the plants received a standard starter solution at the rate of 1 cup per plant. The field was also irrigated with a 1/2 inch application of water at this time.

No pruning or staking was done so that the plants could creep freely over the ground. Throughout the growing season the plot was kept reasonably free of weeds with the use of a rototiller and by hand hoeing. On June 10, a sidedressing was given, using 16-20-0 at the rate of 400 lbs per acre. Data on temperature and precipitation are summarized on page 34. In order to supplement the very scarce rainfall, all plots were irrigated with a perforated pipe sprinkler system. These data are also given in the table on page 34. Since under normal conditions a heavy infestation of all common insect pests of tomatoes occurs at the Horticulture Experiment Farm, no efforts were made to supply an artificial infestation.

On June 5, it was noted that all plants had been more or less seriously injured by 2,4-D from an unknown source (drift). However all plants recovered apparently well and it is not believed that the injury affected the experiment significantly.

No pesticide was applied to the plants for insects or diseases.

Description of Insect Pests

The adults of the tomato hornworm, Protoparce quinquemaculata, and the tobacco hornworm, P. sexta, are large gray moths with a wingspread of about 4 inches; the hind wings are banded, and there are five (quinquemaculata) or six (sexta) orange yellow spots along each side of the abdomen. The larvae have a conspicuous horn on the dorsal surface of the eighth abdominal segment (4). A small braconid wasp, Apanteles congregatus, (Say) is a natural parasite of both species of hornworms (10, 28). The parasites are at first internal, but later pupate in white cocoons outside on the back of the hornworm larvae. The moths emerge in June and fly only in the evening or at night. Most of the eggs are laid on the underside of the leaves. The eggs hatch in a few days producing caterpillars which mature in three to four weeks. The larvae pass through five or six instars. When they are full grown, they leave the plant and pupate in the soil at a depth of about 4 inches (10). In Kansas there are 3-4 generations per year. The insect overwinters as a pupae in the soil.

The adult of the tomato fruitworm, Heliothis armigera (Hbn), is a light yellowish moth which flies at night. It has a blackish dot on each front wing and a wingspread of approximately 1.5 inches. The larvae are somewhat striped, stout bodied and sparsely covered with short, dark spines. They vary in color from light gray to greenish brown and black. One "worm" may feed within a single tomato, or it may move from one fruit to another injuring as many as 10 fruits before completing its growth (33). The larvae complete their growth in 2-4 weeks. They pass through about 5 instars. When

full grown, they drop to the ground and enter the soil where they pupate and overwinter as pupae.

Recording the Data

From May 29, until October 5, notes were taken at weekly intervals of the individual insect populations (see sample data sheet in Appendix). The recordings were made for each individual plant. All ripe fruits were harvested each time, counted and evaluated for fruitworm damage. Hornworm damage was measured by counting the number of larvae present. Because of their devastating effect on the plants, the hornworms were destroyed immediately after they had been recorded. This was necessary in order to keep the plants alive and to give the other species a chance to infest these same plants.

Sampling for the flying time of the tomato fruitworm moth was done with the light trap pictured on Plate III.

Statistical Analysis

An analysis of variance was made of the data based on the total number of hornworms recorded, the number of leaves damaged by the hornworm and the percentage of fruits damaged by the fruitworm. Before making the analysis of variance the percentages of the number of fruits damaged by the fruitworm were transformed to the figures for angles as listed by Snedecor (27). In accordance with the same statistician was the transformation of the data for number of hornworms found to the square root of those numbers plus 0.5 before the analysis of variance was made. Since there was no correlation between the size of the means and their variances on the data for the numbers of leaves damaged by the hornworm, these data did not need to be transformed to any other figures and the analysis of variance was made for these data.

EXPLANATION OF PLATE III

Light trap used to determine the flight date of the moth of the tomato fruitworm, *Heliothis armigera* (Hbn.).

PLATE III

After the analysis of variance had been made the null hypothesis was applied based on Fisher's F values. If the calculated F value was smaller than the F value at the 5% level, it was concluded that the observed differences between the varieties or replicates were statistically not significant. A calculated F value larger than the F value at the 5% level was considered to indicate statistically significant differences between the varieties or replicates.

Where such statistically significant differences were found, the standard error of difference (standard deviation) between variety means was then calculated from the analysis of variance table.

$$s_{\bar{D}} = \sqrt{\frac{2\ V_E}{r}}$$

where $s_{\bar{D}}$ is the standard error of difference between any pair of variety means.

V_E is the estimated variance of the error (within varieties).

r is the number of replicates.

The standard error of difference between replicate means is calculated the same way, except that the value k is used instead of r. The formula for replicate means would then be as follows:

$$s_{\bar{D}} = \sqrt{\frac{2\ V_E}{k}}$$

where k is the number of varieties.

The necessary difference between any pair of variety means for significance is:

$$t_{.05} \times s_{\bar{D}}$$

$t_{.05}$ is Fisher's t value at the 5% level. This value must be found for the same number of degrees of freedom as for which $s_{\bar{D}}$ was calculated.

It must be noted that the use of the necessary difference as a test criterion is valid only when the two means have been randomly selected.

RESULTS AND DISCUSSION

Tomato Hornworm

The hornworm population was quite heavy from the beginning of July through the remainder of the season. As was mentioned before, some braconid species are natural parasites of hornworms, but only a very few hornworms were observed with the typical white cocoons on their back. Although the damage was noted each week, the worms which had caused this damage were not always found. It is possible that birds had eaten the hornworms.

The results of the analysis of variance on the transformed data for the number of hornworms that were found on each variety are shown in Table 1.

Table 1. Analysis of variance for number of tomato hornworms. (transformed data)

Source of variation	Sum of squares	Degrees of freedom	Estimated variance	F observed	F .01	F .05
Varieties	8.20	24	.341	1.39	2.06	1.67
Replications	1.32	3	.440	1.79	4.07	2.74
Error	17.68	72	.245			
Total	27.20	99				

Here it may be concluded that differences between varieties are not statistically significant. This may mean that the adult female moths show no varietal preference for oviposition. However a highly significant difference was observed between varieties in the number of leaves damaged by the hornworms

which indicates a definite preference for feeding. This can be seen in Table 2.

Table 2. Analysis of variance for number of leaves damaged by the tomato hornworm.

Source of variation	Sum of squares	Degrees of freedom	Estimated variance	F observed	F .01	F .05
Varieties	37013	24	1541	2.98	2.06	1.64
Replications	4361	3	1453	2.77	4.07	2.74
Error	37721	72	523			
Total	79095	99				

It will be noted that differences between replications are also significant. This would emphasize the importance of the design and layout of the replicates in an experiment of this kind.

The degree of injury of the replicates is listed in Tables 3 and 4.

Table 3. Injury from tomato hornworm on the foliage.

Replicate	Mean no. leaves damaged
I	69.6
II	51.1
III	62.4
IV	60.6

The standard error of difference between any pair of replicate means is calculated:

$$s_{\bar{D}} = \sqrt{\frac{2 \times 523}{25}} = 6.46$$

The necessary difference between any pair of replicate means is:

$$t_{.05} \times s_{\bar{D}} = 3.18 \times 6.46 = 20.54$$

Thus there is only a significant difference between replicates I and II.

The following table shows the degree of injury for varieties:

Table 4. Foliage injury by tomato hornworm.

Variety	Mean No. Leaves Damaged per Replicate	Variety	Mean No. Leaves Damaged per Replicate
Smoothie	17.2	Alpha 425	70.5
Fireball	18.5	Cardinal	71.0
Success	35.0	59-61	71.0
K.S. 56-5	40.0	Red Cherry	71.2
K.S. 59-2	42.2	Marion	72.0
Heinz 1350	44.0	Mo. 20 stake 15	72.5
K.S. 57-1	52.0	Mo. 22 stake 5	72.5
Mocross Supreme	53.0	Alpha 440	75.5
Alpha 417	55.5	Glamour	81.0
K.S. 56-8	56.0	Tomboy	82.2
Gardner	58.0	Alpha 536	82.5
Wonderboy	64.8	Mo. 20 stake 4	95.5
420-60	65.0		

The standard error of difference between any pair of variety means is as follows:

$$s_{\bar{D}} = \sqrt{\frac{2 \times 526}{4}} = 16.3$$

The necessary difference between any pair of variety means is:

$$t_{.05} \times s_{\bar{D}} = 2.00 \times 16.3 = 32.6$$

Although there is a significant difference in the number of leaves damaged, results concerning resistance to the hornworm are still inconclusive. It was mentioned before that for practical reasons the hornworms were destroyed when they were found at the weekly observations, therefore greater injury might have occurred had they been allowed to feed for a longer period of time. Thus the time when the insect was found was the limit to the total number of damaged leaves. The factor earliness also may have played a role

in these data. For instance it would have been possible for the early variety Fireball to have escaped damage, rather than have resistance to the insect. Another possible criterion, which was not used in this experiment and would be rather time consuming, would be to weigh the hornworms and measure their gain in weight for a certain number of days or to measure the time necessary for them to reach a certain weight. The data collected would give a better indication of preference for oviposition by the adult moths than for tolerance or antibiosis.

Because of the large number of variables which were encountered in this experiment, it might be better to conduct future experiments in a more controlled environment where the effects of natural predators and the spread of virus diseases could be ruled out to a large extent. Growing the plants in or under screen cages may be a partial answer to this problem.

In order to measure resistance to the hornworm, perhaps an experiment should be set up for this insect alone so that the hornworms would not need to be destroyed in order to save the plant for the other pests. Such an experiment probably would require a larger number of plants of each variety per replicate.

Tomato Fruitworm

The majority of fruits which were damaged by the fruitworms were picked after September 1, although the harvesting of the early varieties was started in mid July. This delay in infestation is believed to be caused by the presence of a plot of several varieties of sweet corn nearby. Few damaged fruits were noted until some time after the sweet corn had been harvested. Painter (21) states that early generations of the larvae feed in the whorl of young corn plants and that larvae of later generations feed on the silk and developing

EXPLANATION OF PLATE IV

Larva of the tomato fruitworm, Heliothis armigera (Hbn.) in damaged fruit. September 1963

PLATE IV

ear. When silks are available, the adult moths show a decided preference for oviposition for them.

The analysis of variance on the angles of the percentage of the number of fruits damaged is given in Table 5.

Table 5. Analysis of variance for percent of damaged fruits by tomato fruitworm. (transformed data)

Source of variation	Sum of squares	Degrees of freedom	Estimated variance	F observed	F .01	F .05
Varieties	3348	24	139.0	1.12	2.06	1.67
Replications	34	3	11.3	.09	26.27	8.57
Error	8958	72	124.0			
Total	12340	99				

Since the calculated F value (1.12) is smaller than the F value at the 5% level (1.67) we can conclude that the calculated F value would occur more often than 5% of the time due to random sampling alone, or that the differences in the observed data are not significant.

Other Insects

Contrary to what was expected, the populations of aphids, blister beetles and spider mites were so low, that no reliable data indicating differential attack could be gathered. It is believed that exceptionally extreme dry weather conditions (see page 34) were the cause of the very low infestation levels of these pests. Also, the preceeding severe winter probably lowered overwintering populations.

On May 29, and June 5, some aphids were found, but none were found during the remainder of the summer. Few ladybird beetles, <u>Hippodamia convergens</u> (Guerin) were present throughout the season. Since the ladybird beetles are

natural aphid predators it is possible that they devoured whatever few aphids did occur. In general, however, an increase in the population of ladybird beetles takes place after a plentiful food source (i.e. aphids) is available. Since the ladybird beetle population remained very low throughout the season it can be assumed that these beetles were not the primary cause of the low aphid infestation.

No mite infestation occurred in the tomato plot until late in the season when slight damage was noted. In an adjacent watermelon breeding plot, however, some areas became seriously infested with mites from plants infested in the greenhouse prior to transplanting. However, the population did not spread to the tomato planting.

The population of blister beetles was practically nil on the tomatoes as well as on the surrounding crops (potatoes, tomatoes, sweet corn, watermelon, muskmelon, soybeans), although the author did notice severe blister beetle infestations in tomatoes in home gardens elsewhere in Kansas.

A considerable virus infection was observed in this experiment. Plants were observed to be suffering from the following virus diseases:

Sugar beet curlytop, _Ruga verrucosans_ (Carsner and Bennett)

Cucumber mosaic (Shoestring), _Marmor cucumeris_ (H.)

Tobacco mosaic, _Marmor tabaci_ (H.)

Of the total of 400 plants in the experiment, by October 10, 9 plants were infected with curlytop, 25 plants with shoestring and 88 plants with tobacco mosaic virus. Most plants that showed signs of curlytop died. The plants infected with shoestring seemed to produce less fruits than the healthy plants. Plants infected with the tobacco mosaic did not seem to be seriously affected in their yield. Hornworms and fruitworms were both observed on leaves and fruits respectively of plants that showed signs of these diseases. Since

so few aphids occurred it may well have been that the hornworm played a part in the transmission of some of these virus diseases. Some cucumber beetles were also observed on the tomatoes and they too may have played a role.

The presence of some beet leafhoppers, Circulifer tenellus (Baker) was also observed. The beet leafhopper is definitely known to transmit the sugar beet curlytop virus.

SUMMARY AND CONCLUSION

Since no data were available from previous research on these insects, methods must be developed for measuring resistance. This study contributed to this end and will be valuable for future studies.

A significant difference was found in the number of leaves damaged by the hornworms. The varieties with the least number of leaves damaged were Smoothie and Fireball, while Mo. 20 stake 4 had more leaves damaged than any other variety in this experiment. No significant difference could be detected on the number of hornworms collected from the varieties. This might indicate no difference in preference for oviposition, but a preference for feeding.

There was also a significant difference between replicates on the number of leaves damaged by the hornworm. This would indicate that the activity of this insect is localized, and this factor will have to be taken into account in the design of future experiments.

No significant difference could be detected between varieties in their susceptibility to injury by the tomato fruit worm.

Because of extremely low populations of aphids, blister beetles and two spotted spider mites, no data could be collected on these pests, although they sometimes seriously injure field tomatoes in Kansas.

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APPENDIX

Table 6. Temperature and precipitation at the K.S.U. Ashland Agronomy Farm in summer 1963.
(Data supplied by the K.S.U. Department of Physics)

Week		Temperature			Precip.	Irrigation
		Max.	Min.	Aver.		
April	5-11	78	32	53.3	.05	
	12-18	85	31	59.6	.14	
	19-25	80	35	53.5	.00	
	26-May 2	81	32	57.0	1.20	
May	3- 9	93	51	72.1	.07	.5
	10-16	90	54	69.6	.65	
	17-23	80	35	56.6	.69	
	24-30	84	49	64.9	.60	
	31-June 6	95	62	76.0	.25	
June	7-13	98	58	79.9	.72	.75
	14-20	96	53	72.0	1.36	
	21-27	98	61	77.6	.20	
	28-July 4	102	73	85.9	.00	1.00
July	5-11	103	61	78.7	.23	
	12-18	100	63	80.4	.84	1.00
	19-25	107	67	86.6	.05	
	26-Aug. 1	102	60	80.6	.05	1.00
Aug.	2- 8	107	67	86.3	.10	
	9-15	97	55	77.0	.06	1.00
	16-22	101	58	74.6	1.82	
	23-29	105	68	82.7	.03	
	30-Sep. 5	90	56	74.3	.29	
Sept.	6-12	95	63	78.6	.02	
	13-19	88	54	70.0	1.61	
	20-26	86	50	69.6	.09	
	27-Oct. 3	96	49	67.0	.00	
Oct.	4-10	97	51	73.3	.00	
	11-17	89	49	68.8	.01	
	18-24	87	57	70.3	1.38	
	25-31	82	29	55.4	.65	
	Total rainfall April 5-October 31				13.16	
	Total irrigation in growing season					5.25

Sample Data Sheet

Plant 1

Date	Tot. Ripe Frt.	Aph. No. Lvs. Inf.	Fruitw. No. Frt. Inf.	Hornw. No. Ins.	No. Lvs. Inf.	Blister Beetle Ins.	Inj.	Mites	Remarks
Plant 2									

INSECT RESISTANCE OF THE TOMATO,
Lycopersicon esculentum (Mill.)

by

HIELKE DE JONG

Gerard Adriaan van Swieten Middelbare
Tuinbouwschool, Frederiksoord, Neth. 1954

B.A. Bethel College 1959

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

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OF AGRICULTURE AND APPLIED SCIENCE

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The tomato is attacked by a large number of insects. Chemical control measures frequently cannot be used because insects attack the plants and fruits near or during harvest season, therefore residues will remain on the fruits after spraying or dusting.

Very little research has been done on insect resistance in tomatoes. Workers in Europe have found resistance in the tomato to the Colorado potato beetle, Leptinotarsa decemlineata (Say). Stimulants for oviposition and leaf feeding of the tobacco hornworm, Protoparce sexta, have been analyzed.

In the summer of 1963 a survey was made to assess possible sources of insect resistance in 25 commercial tomato varieties. Probably due to the preceeding severe winter and the extremely dry weather conditions during the season natural infestation was extremely low for several insect species which normally present a problem on tomatoes in Kansas. A natural infestation did occur of the tomato fruitworm, Heliothis armigera (Hbn) and the tomato hornworm, Protoparce quinquemaculata (Haw.).

Analysis of variance on the percentage of damaged fruit by the tomato fruitworm showed that the observed difference was not significant.

The difference in numbers of hornworms observed, was also insignificant. There was a significant difference between varieties in the number of leaves damaged by the hornworm. The varieties Smoothie and Fireball showed the least and Mo. 20 stake 4 the most damage. The early varieties may have been able to escape part of the damage.

There was also a significant difference between replicate I and II, which would emphasize the importance of experimental design.

Since no data were available from previous research on these insects, methods must be developed for measuring resistance. This study contributed